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04 Neural Control and Coordination

1. Introduction :

- To maintain homeostasis of the body functions of the organs/organ systems in our body must be coordinated.
- Coordination is the process through which two or more organs interact and complement the functions of one another.

For example-

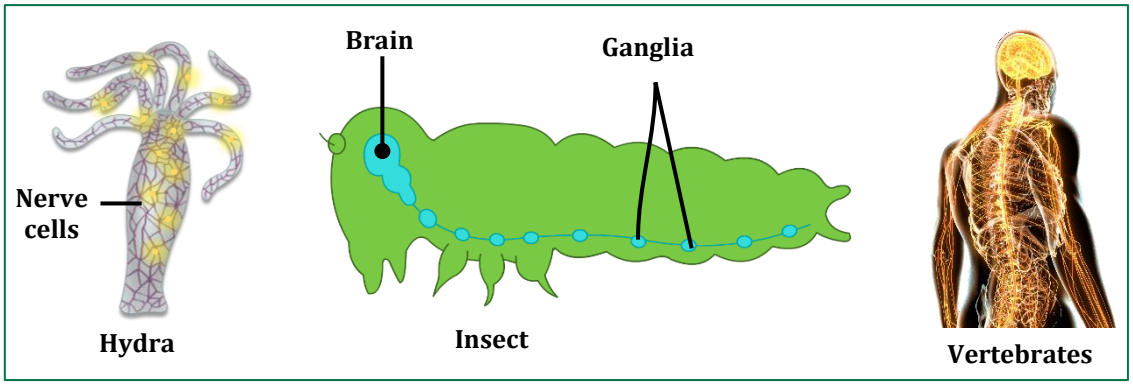
(a) **When we do physical exercises,** the energy demand is increased for maintaining an increased muscular activity, for that the supply of oxygen is also increased. The increased supply of oxygen necessitates an increase in the rate of respiration, heart beat and increased blood flow via blood vessels.

(b) **When physical exercise is stopped,** the activities of nerves, lungs, heart and kidney gradually return to their normal state thus, the functions of muscles, lungs, heart, blood vessels, kidney and other organs are coordinated while performing physical exercises.

- In human body the neural system and the endocrine system jointly coordinate and integrate all the activities of the body so that the organs function in a **synchronised fashion.**
- Nervous system and endocrine system are called **Integrative system of the body.**
- The neural system provides an organised network of point-to-point connections for a quick coordination and the endocrine system provides chemical integration through hormones.

2. Neural System :

- The neural system of all animals is composed of highly specialised cells called **neurons** which can detect, receive and transmit different kinds of stimuli.
- The neural organisation is **very simple** in lower invertebrates. For example, in ***Hydra*** it is composed of a network of neurons.
- The neural system is **better organised** in **insects**, where a brain is present along with a number of ganglia and neural tissues.
- **Vertebrates** have a more developed neural system.



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3. Human Neural System :

- The human neural system is divided into two parts :

  Central neural system (CNS) : The CNS includes the **brain** and the **spinal cord** and is the site of **information processing and control**.

  Peripheral neural system (PNS) : The PNS comprises of **all the nerves** of the body associated with the CNS (brain and spinal cord).

Peripheral Nervous System (PNS)

Afferent fibres	Efferent fibres
The afferent nerve fibres transmit impulses from **tissues/organs to the CNS**.	The efferent fibres transmit regulatory impulses from the **CNS to the concerned peripheral tissues/organs**.

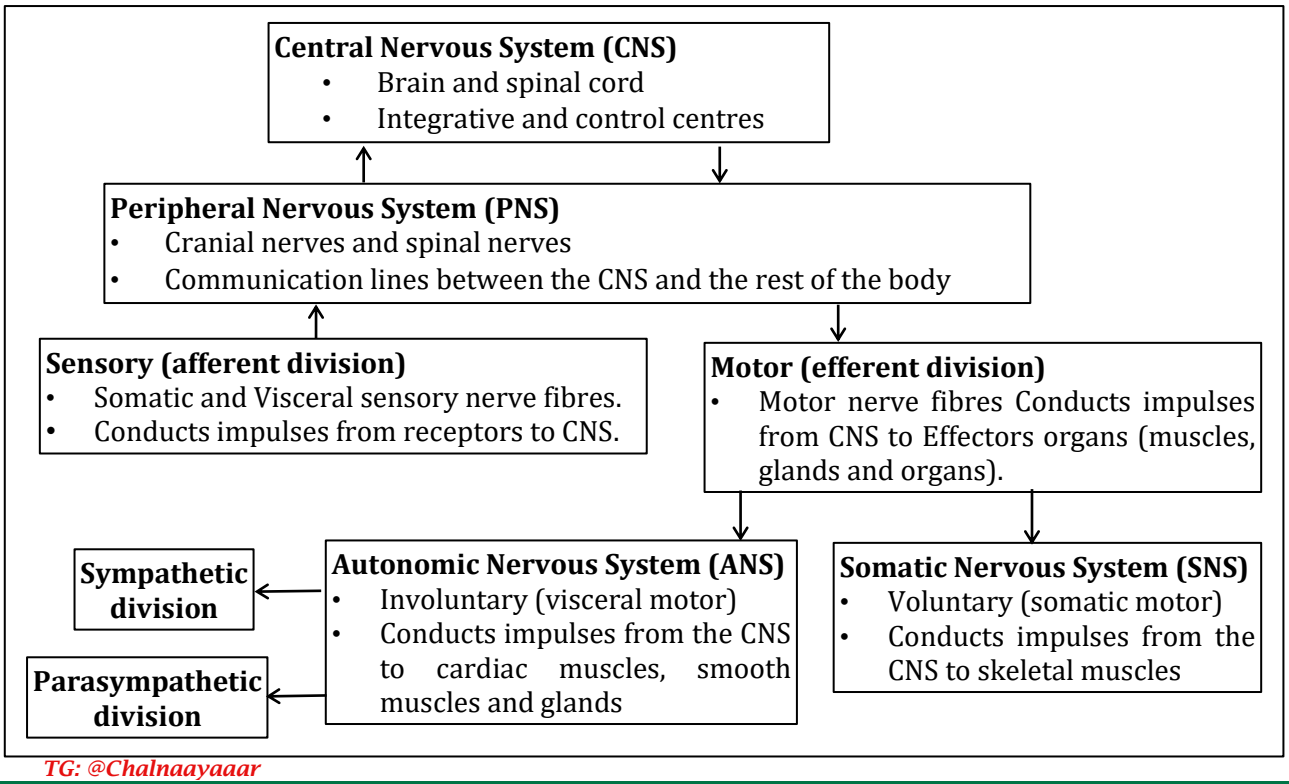
- The PNS is divided into two divisions :-

  (A) Somatic neural system (SNS) : It relays impulses from the CNS to skeletal muscles and voluntary organs.

  (B) Autonomic neural system (ANS) : It transmits impulses from the CNS to the involuntary organs and smooth muscles of the body. The autonomic neural system is further classified into sympathetic neural system and parasympathetic neural system.

Autonomic neural system

Sympathetic neural system	Parasympathetic neural system
• Works in during emergency condition. • Prepare us for stressful conditions.	• Works in during normal life. • Relaxes us after stress is over.


Central Nervous System (CNS)
• Brain and spinal cord
• Integrative and control centres
Peripheral Nervous System (PNS)
• Cranial nerves and spinal nerves
• Communication lines between the CNS and the rest of the body
Sensory (afferent division)
• Somatic and Visceral sensory nerve fibres.
• Conducts impulses from receptors to CNS.
Motor (efferent division)
• Motor nerve fibres Conducts impulses from CNS to Effectors organs (muscles, glands and organs).
Sympathetic division
Parasympathetic division
Autonomic Nervous System (ANS)
• Involuntary (visceral motor)
• Conducts impulses from the CNS to cardiac muscles, smooth muscles and glands
Somatic Nervous System (SNS)
• Voluntary (somatic motor)
• Conducts impulses from the CNS to skeletal muscles

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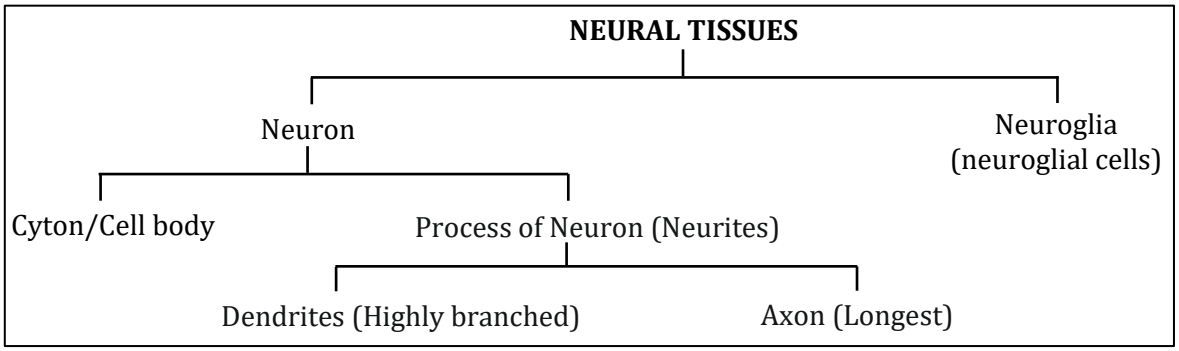
- **Visceral nervous system** is the part of the peripheral nervous system that comprises the whole complex of nerves, fibres, ganglia, and plexuses by which impulses travel from the central nervous system to the viscera and from the viscera to the central nervous system.

4. Nervous Tissue :

- Nervous tissue originates from **ectoderm** and is specialized for receiving stimuli (Excitability) and transmit message (conductivity).

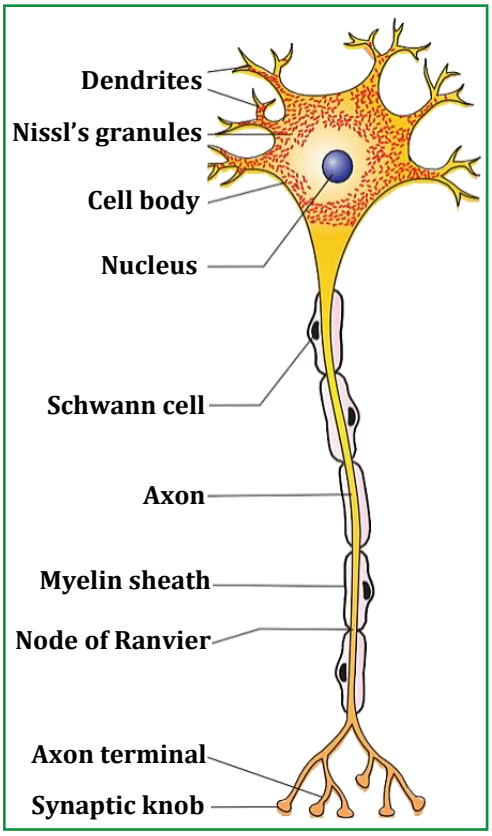


(A) Neuron (Nerve Cell) :

- It is the **functional and structural unit** of nervous system.
- It generates and transmits nerve impulses.
- It is the longest cell of the body.

A neuron is a microscopic structure composed of three major parts, namely :-

(i) Cell body or Cyton
(ii) Dendrites or dendrons
(iii) Axon



(i) Cell Body or Cyton or Soma or Perikaryon :

- The cell body contains cytoplasm with typical cell organelles and certain granular bodies called **Nissl's granules**.
- Except centriole, all cell organelles are found in cytoplasm.
- Centriole is absent in the nerve cell thus cell division is absent.
- Neurofibril are also found in nerve cell.

Nissl's granules

- Endoplasmic reticulum & ribosome form granules like structure.
- These are the centre of protein synthesis.
- Site of Nissl's Granules - Cyton & dendron.

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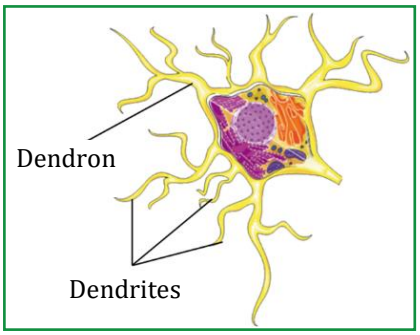
Neurofibrils

- Many small fibrils are found in the cytoplasm called neurofibrils, these help in internal conduction in the cyton.
- Site of Neurofibrils – Cyton, dendron & Axon

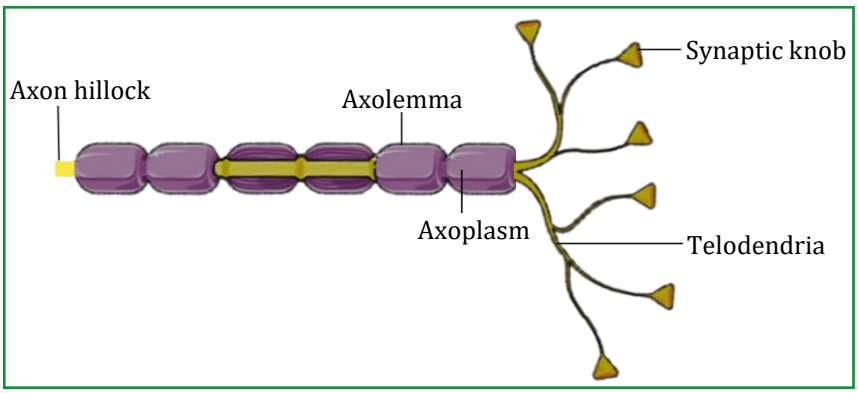


(ii) Dendrites or Dendrons :

- Short fibers
- Branch repeatedly
- Project out of the cell body
- Also contain Nissl's granules
- These fibers transmit impulses towards the cell body **(Centripetal Conduction).**

(iii) Axon :

- The axon is a long fibre, the distal end of axon is branched called telodendria.
- Axon is covered by Axolemma.
- Part of cyton where axon arises is called Axon hillock.
- Cytoplasm which contains in axon is called axoplasm.
- Each branch terminates as a bulb-like structure called synaptic knob which possess synaptic vesicles containing chemicals called neurotransmitters.
- The axon transmit nerve impulses away from the cell body to a synapse or to a neuro-muscular junction.
- Nissl's granules are absent in the axoplasm.
- Conduction is centrifugal.



(B) Myelinogenesis :

- Myelin is a fatty material (Phospholipids) with a high electrical resistance and acts as an electrical insulator in the same way as the rubber and plastic covering of electrical wiring.

MYELINOGENESIS In (Carried out by)
- CNS — Oligodendrocytes (Neuroglia)
- PNS — Schwann Cell

(i) Myelinogenesis in PNS :

- Axon is covered by a layer of phospholipids/sphingomyelin which is called as medulla or myelin sheath.
- Schwann cell takes part in the deposition of myelin sheath (myelinogenesis) across Axon.
- Myelin sheath acts as insulator and prevents leakage of ions.
- The neurilemma is membrane of Schwann cells.

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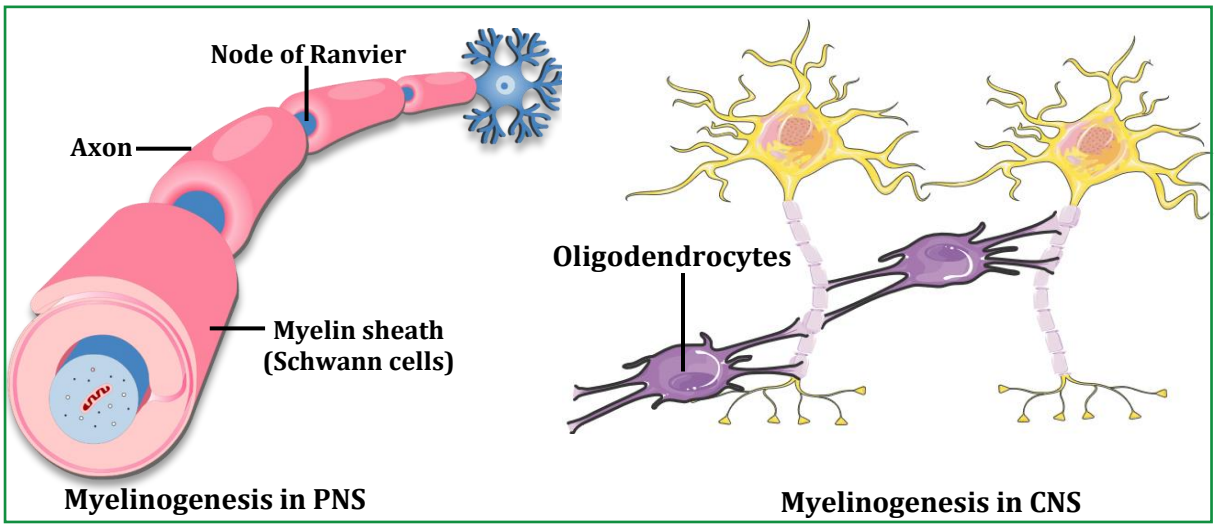
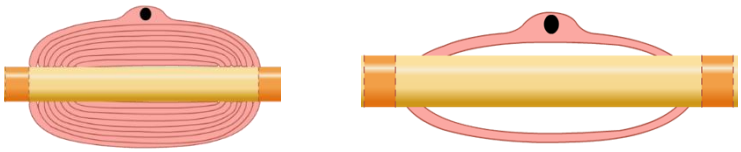
- In the peripheral nerves, myelinogenesis begins with the deposition of myelin sheath in concentric layer around the axon by Schwann cells.
- Myelin sheath is discontinuous around the Axon.
- Those interruptions where axon is uncovered by myelin sheath are called 'Nodes of Ranvier'.

(ii) Myelinogenesis in CNS :

- Neurilemma or schwann cells are not present in CNS, therefore myelinogenesis process occurs with the help of oligodendrocytes (Neuroglia).



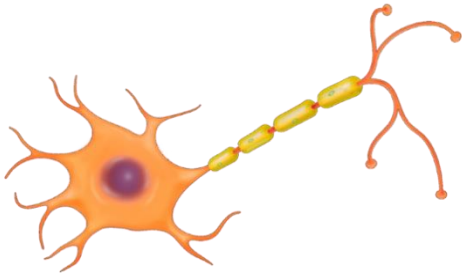
- **Myelinated nerve fibres are found in spinal and cranial nerves. Unmyelinated nerve fibres which are enclosed by a Schwann cell that does not form a myelin sheath around the axon, and is commonly found in autonomous and the somatic neural systems.**



(C) Types of Neuron :

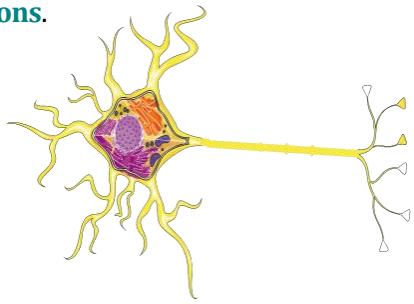
(i) On The Basis of Myelinogenesis :

Neurons in which myelin sheath is present, are called **medullated or myelinated neurons**.



Myelinated

In some nerve cells where myelin sheath is absent, called as **non-medullated or non-myelinated neurons**.



Neuron

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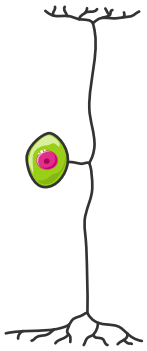
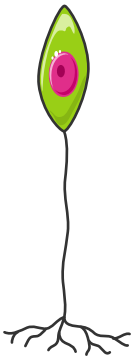
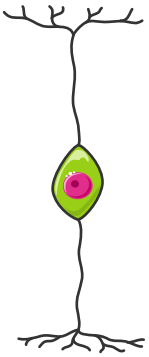
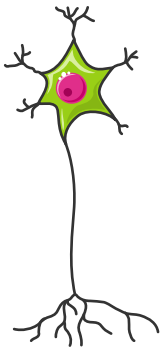
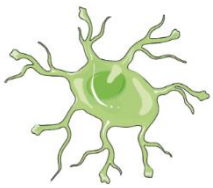
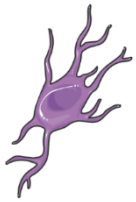
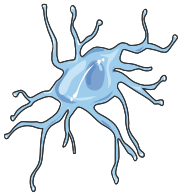
(ii) On the basis of number of Dendron & Axon :

Apolar/Nonpolar	Pseudounipolar	Unipolar	Bipolar	Multipolar
No definite dendron/axon. Cell process are either absent or if present are not differentiated in axon and dendrons. Nerve impulse radiates in all directions.	In this type, nerve cell has only axon but a small process develops from axon which act as dendron.	Single process arises from cyton. (1 Axon)	Two process arises from cyton (1 Axon & 1 dendron).	Neuron which have one axon but many dendrons.
e.g.: (i) Hydra (ii) Amacrine cell of retina.	**e.g.:** (i) Dorsal root ganglia of spinal cord.	**e.g.:** (i) Nervous system of embryo	**e.g.:** Retina (i) Rod and cones (modified bipolar neurons) (ii) Bipolar neuron layer of retina	**e.g.:** (i) Most neurons of vertebrates (cerebral Cortex).
				

(D) Neuroglia/Glial Cells :

	Astrocytes	Oligodendrocytes	Microgliocytes
Morphology	Large cell having numerous process	Smaller cells with few processes.	Smallest cells with Branching.
Function	It forms blood brain barrier	Formation & preservation of Myelin sheath in CNS.	Scavenger cells of CNS and phagocytic in nature.
			

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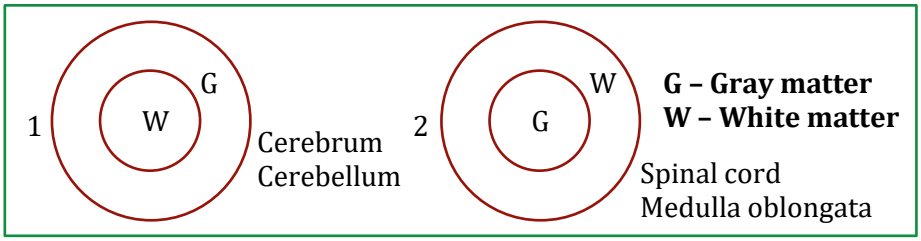
Gray matter : It is composed of **nerve cells**. It consists of cytons & nonmedullated nerve fibres (Gray fibers).

White matter : It contains myelinated **nerve fibres** (White fibres).



Important terms to remember :

Collection of cytons → **Nuclei –** term used for CNS (Brain and spinal cord)

Collection of cytons → **Ganglia –** outside the CNS term used for PNS

Collection of nerve fibre → **Tract** – CNS

Collection of nerve fibre → **Nerve** – PNS

BEGINNER'S BOX-1 NEURAL TISSUE

1. Which statement is correct about nerve fibres ?
(1) All nerve fibres of CNS are enclosed by Schwann cells.
(2) Only myelinated nerve fibres of PNS are enclosed by Schwann cells.
(3) All nerve fibres of PNS are enclosed by Schwann cells.
(4) Only myelinated fibres of CNS are enclosed by Schwann cells.

2. Which statement is true ?
(1) In PNS, only non-myelinated neuron are found.
(2) In CNS, myelinated and non-myelinated neurons are found.
(3) In PNS, myelinated and non-myelinated neurons are found.
(4) Both (2) and (3)

3. Which structure is not found in white matter ?
(1) Telodendria
(2) Cell body
(3) Dendrons and non-myelinated axons
(4) All of the above

4. Which of the following is true for Neurilemma ?
(1) Discontinuous at nodes of Ranvier
(2) Continuous at nodes of Ranvier and made by schwann cells
(3) Discontinuous at nodes of Ranvier and made by schwann cells
(4) Continuous at nodes of Ranvier and made by oligodendrocytes

5. Fibres which transmit impulses towards the cell body called as :-
(1) Axon terminal (2) Axon
(3) Dendrites (4) Axon hillock

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6. The nerves leading to the central nervous system are called :-
(1) Afferent (2) Efferent (3) Motor (4) None

7. In which animal, nerve cell is present but brain is absent ?
(1) Sponge (2) Earthworm (3) Cockroach (4) Hydra

8. Which system work during Emergency ?
(1) Sympathetic Nervous System (2) Para Sympathetic System
(3) Somatic Nervous System (4) All of above

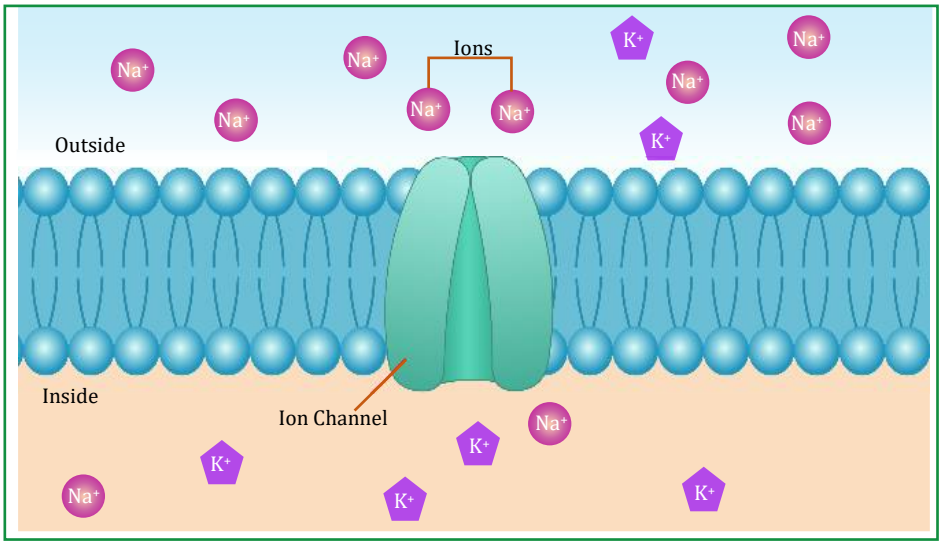
9. The nervous system is derived from :-
(1) Ectoderm (2) Endoderm
(3) Mesoderm (4) Ectoderm and Mesoderm

5. Generation and Conduction of Nerve Impulse : (Conduction of Nerve Impulse Along the Axon) :

Neurons are excitable cells because their membranes are in a polarised state.

Q. Do you know why the membrane of a neuron is polarised?

Neuron itself in a salt solution with higher concentration of Na^+ ions, inside neuron there is high concentration of K^+. Different types of ion channels are present on the neural membrane. These ion channels are selectively permeable to different ions.



(A) Resting Phase (Polarisation) :

- When a neuron is not conducting any impulse, i.e. resting, the axonal membrane is comparatively more permeable to potassium ions (K^+) and nearly impermeable to sodium ions (Na^+).
- Similarly, the membrane is impermeable to negatively charged proteins present in the axoplasm (neuroplasm of axon).
- Consequently, the axoplasm inside the axon contains high concentration of K^+ and negatively charged proteins and low concentration of Na^+. In contrast, the fluid outside the axon contains a low concentration of K^+, a high concentration of Na^+ and thus forms a **concentration gradient**.
- The ionic gradients are maintained by **Sodium-potassium pump which transports $3Na^+$ outwards for $2K^+$ into the cell actively using ATP**.

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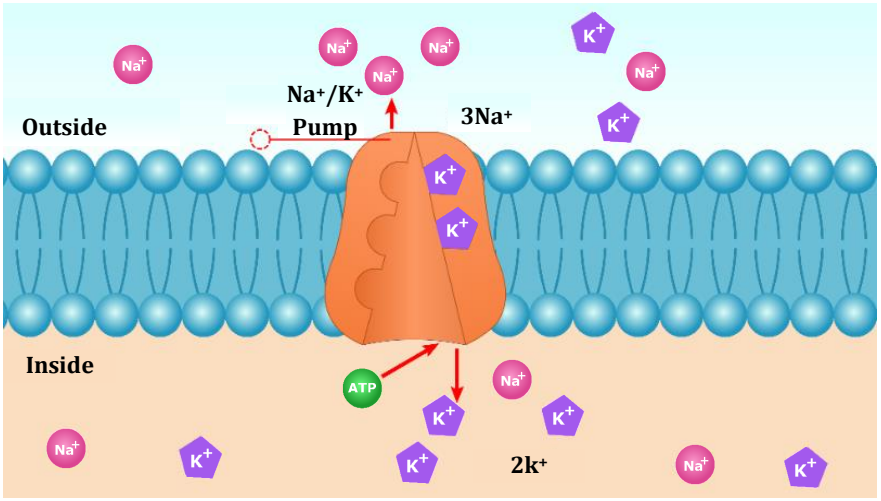
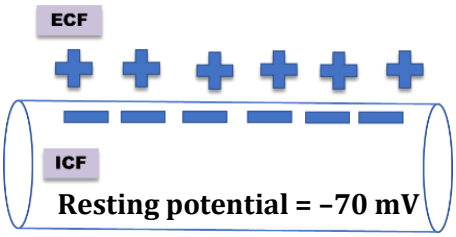
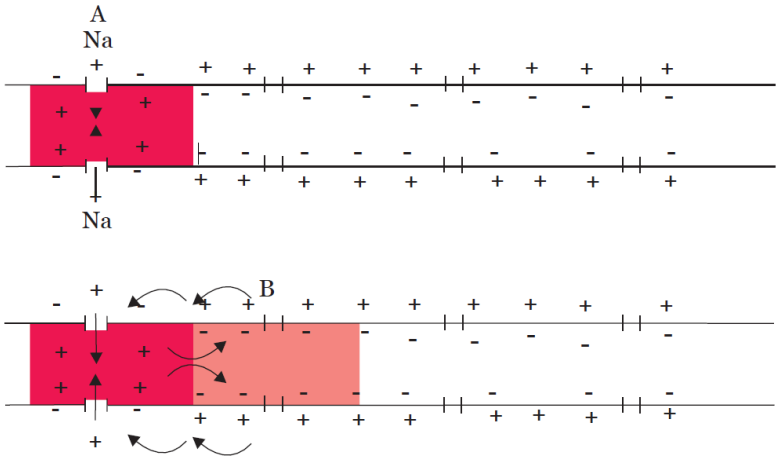


- As a result, the outer surface of the axonal membrane possesses a positive charge while its inner surface becomes negatively charged and therefore, is said to be **polarised**. The electrical potential difference across the resting plasma membrane is called as the **resting potential**.



(B) Action Potential (Depolarisation) :

- When a stimulus is applied at a site **(point A)** on the polarised membrane, the permeability of the membrane to Na^+ ions is greatly increased at the point of stimulation **(point A)**.
- It is due to the fact the Na^+ channels open and the K^+ channels remain closed. As a result, sodium channels permit the rapid **influx of Na^+** ions by diffusion followed by the reversal of the polarity at that site, i.e., the outer surface of the membrane becomes negatively charged and the inner side becomes positively charged.
- The polarity of the membrane at the site A is thus reversed and hence **depolarised**.
- The electrical potential difference across the plasma membrane at the site A which can induce impulse is called the **action potential**, which is in fact termed as a **nerve impulse**.
- At sites immediately ahead, the axon (**e.g., site B**) membrane has a positive charge on the outer surface and a negative charge on its inner surface.



Diagrammatic representation of impulse conduction through an axon (at points A and B)

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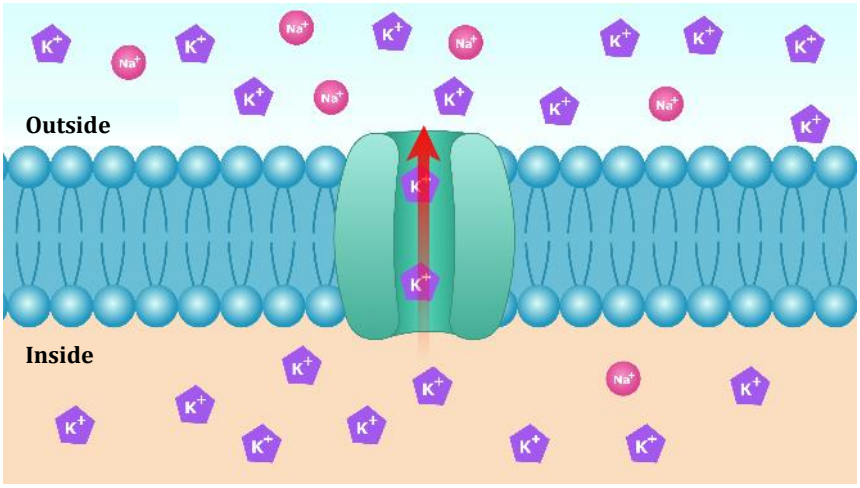
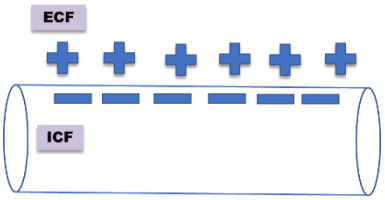
- As a result, a **current flow on the inner surface from site A to site B**. On the outer surface current flows from site B to site A to complete the circuit of current flow.
- Hence, the polarity at the site is reversed, and an action potential is generated at site B. Thus, the impulse (action potential) generated at site A arrives at site B. The sequence is repeated along the length of the axon and consequently the impulse is conducted.

(C) Repolarisation :

- The **rise in the stimulus-induced permeability** to Na^+ is extremely short lived. It is quickly followed by a rise in permeability to K^+ due to opening of K^+ gated channel. Within a fraction of a second, K^+ diffuses outside the membrane and restores the resting potential of the membrane at the site of excitation and the fibre becomes once more responsive to further stimulation.
- With the increase of Na^+ ions inside the nerve fibre, the membrane becomes less permeable to Na^+ ions and more permeable to K^+ ions. Na^+ influx stops and K^+ outflow begins until the original resting state of ionic concentration is achieved. Thus, resting potential is restored which is called **repolarisation** of the membrane.

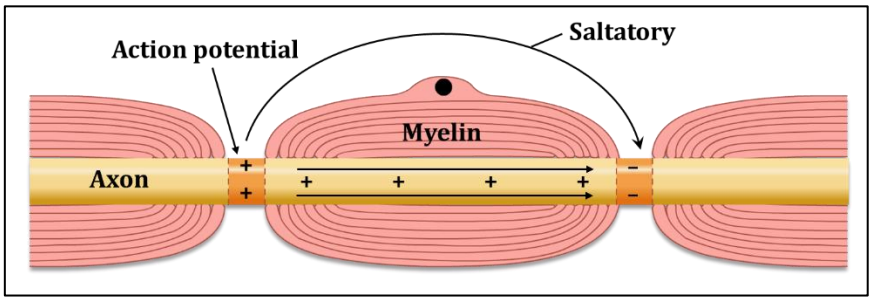


K^+ Voltage Gated channels (VGCs)



(D) Saltatory Conduction of Nerve Impulse :

- This type of conduction occurs in myelinated nerve fibres.
- This means, in effect that the action potential jumps from node to node and passes along the myelinated axon faster as compared to the series of small local circuits in a non-myelinated axon.
- This type of conduction is called saltatory conduction.
- Leakage of ions takes place only in nodes of Ranvier and less energy is required for saltatory conduction.



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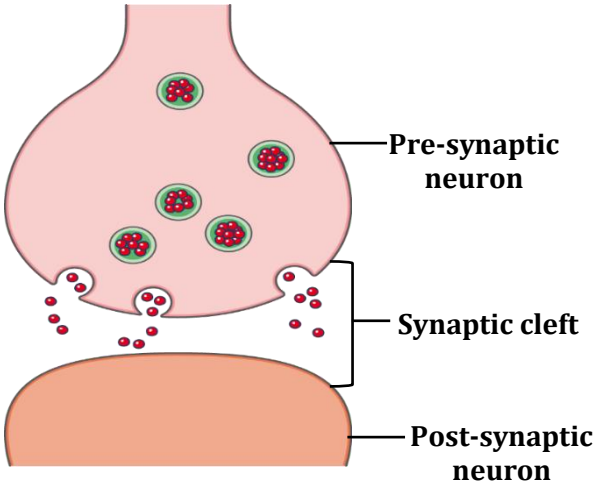
6. Synapse :

- A nerve impulse is transmitted from one neuron to another through junctions called synapses.
- A synapse is formed by the membranes of a pre-synaptic neuron and a post- synaptic neuron, which may or may not be separated by a gap called synaptic cleft.
- There are two types of synapses, namely-
  (i) Electrical synapses
  (ii) Chemical synapses.



(i) Electrical Synapse :

- At electrical synapses, the membranes of pre and post-synaptic neurons are in very close proximity.
- Electrical current can flow directly from one neuron onto the other across these synapses.
- Transmission of an impulse across electrical synapses is very similar to impulse conduction along a single axon.
- Impulse transmission across an electrical synapse is always faster than that across a chemical synapse.
- Electrical synapses are rare in our body.

(ii) Chemical Synapse :

- At a chemical synapse, the membranes of the pre and post-synaptic neurons are separated by a fluid-filled space called synaptic cleft.
- Chemicals called neurotransmitters are involved in the transmission of impulses at these synapses.
- The axon terminals contain vesicles filled with these neurotransmitters.
- When an impulse (action potential) arrives at the axon terminal, it stimulates the movement of the synaptic vesicles towards the membrane where they fuse with the plasma membrane and release their neurotransmitters in the synaptic cleft.
- The released neurotransmitters bind to their specific receptors, present on the post-synaptic membrane.
- This binding opens ion channels allowing the entry of ions which can generate a new potential in the post-synaptic neuron. The new potential developed may be either **excitatory (EPSP)** or **inhibitory (IPSP)**.
- On the rest of the Ach, cholinesterase enzyme functions, which is found in synaptic cleft. This enzyme decomposes the Ach into choline & Acetate.
  (∴ Ach = Acetylcholine)

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7. Neurotransmitters :

Neurotransmitters or Neurohumors or Neurohormones

Stimulator

- Open Na^+ ion channel
- EPSP (Excitatory Post Synaptic Potential)

e.g.

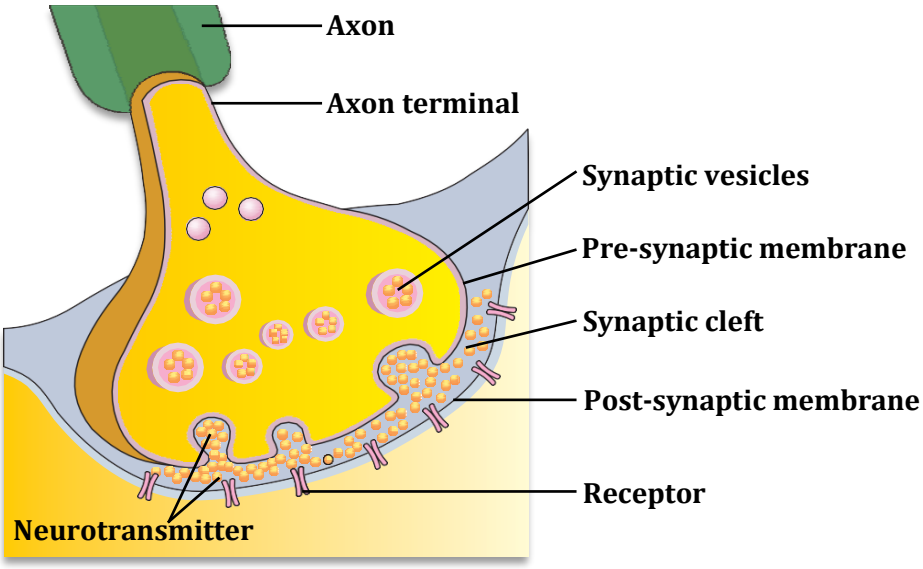
1. Acetylcholine (Ach),
2. Nor-epinephrine or Nor-adrenaline or Sympathetin
3. Glutamate

Inhibitor

- Open Cl^- ion channel
- IPSP (Inhibitory Post Synaptic Potential)
- Causes hyperpolarisation

e.g.

1. GABA (Gamma Amino Butyric Acid)
2. Serotonin,
3. Dopamine,
4. Glycine



★ Golden Key Points ★

- Conduction of nerve impulse is unidirectional.
- It follow **all or none law.** Magnitude of response will always be same irrespective of strength of stimulus above threshold stimulus.
- Velocity of nerve impulse $\propto$ Diameter of neuron.
- This velocity is affected by physical & chemical factor, such as pressure, cold, heat, chloroform and ether etc.
- Depolarization : Na^+ influx.
- Repolarization : K^+ efflux.
- If myelin sheath is continuous there will be no nerve impulse conduction in nerve fibres.
- If question is informing for only about channel opening and closing then consider only VGC.
- Simple diffusion channels are always open (In every state).

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BEGINNER'S BOX-2 NERVE IMPULSE CONDUCTION

1. Which statement is false regarding nerve impulse ?
(1) After applying a stimulus on polarised membrane, that site become freely permeable to Na^+ and leads to rapid efflux of Na^+.
(2) The rise in the stimulus induced permeability to Na^+ is extremely short lived.
(3) After depolarization K^+ diffuses outside the membrane and restores the resting potential.
(4) Ionic gradients across the resting membrane are maintained by the $Na^+ - K^+$ ATPase pump.

2. Resting membrane potential is achieved by :-
(1) Passive diffusion by ion channels/Leaky channels
(2) $Na^+ - K^+$ ATPase pump.
(3) Negatively charged proteins in axoplasm.
(4) All of the above

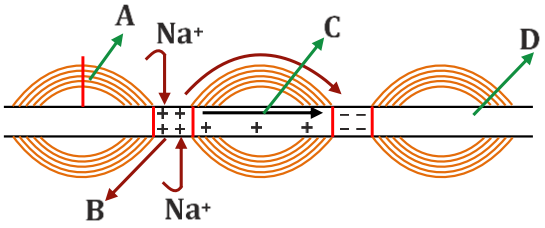
3. Which statement is correct regarding nerve impulse conduction ?
(1) The membrane potential change from positive to negative and then back again.
(2) Sodium ions flow out through ion channels and potassium ions flow in.
(3) Potassium channels close as the membrane potential becomes positive.
(4) The membrane potential becomes less negative due to opening of Na^+ VGC.

4. The axoplasm inside the axon contains high concentration of ..... and ..... :-
(1) K^+ and Na^+ (2) K^+ and Negatively charged proteins
(3) Na^+ and Cl^- (4) Both (1) and (3)

5. The ion channels are ..... to different ions :-
(1) Completely permeable (2) Impermeable
(3) Selectively permeable (4) Both (1) and (3)

6. The electrical potential difference across the plasma membrane at the site of depolarisation is called :-
(1) Graded potential (2) Resting potential (3) Action potential (4) None of the above

7. Given below is the diagram representing conduction of nerve impulse in myelinated neuron label the parts, with correct option:-



(1) A–Axolemma, B–Site of polarisation, C–Wave, D–Axolemma
(2) A–Myelin sheath, B–Site of Depolarisation, C–Action potential jumps from node to node, D–Axoplasm
(3) A–Axoplasm, B–Repolarisation, C–Ionic movement, D–Axon
(4) A–Myelin sheath, B–Hyperpolarisation, C–Action potential, D–Axoplasm

8. Sodium – Potassium pump across membrane, actively transports :-
(1) 2 Na ions outwards and 3 K ions into the cell.
(2) 3 Na ions outwards and 2 K ions into the cell.
(3) 2 K ions outwards and 3 Na ions into the cell.
(4) 3 K ions outwards and 2 Na ions into the cell.

9. The axonal membrane is ___ to negatively charged proteins present in the axoplasm :-
(1) Selectively permeable (2) Permeable
(3) Semipermeable (4) Impermeable

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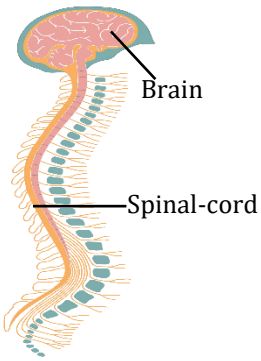
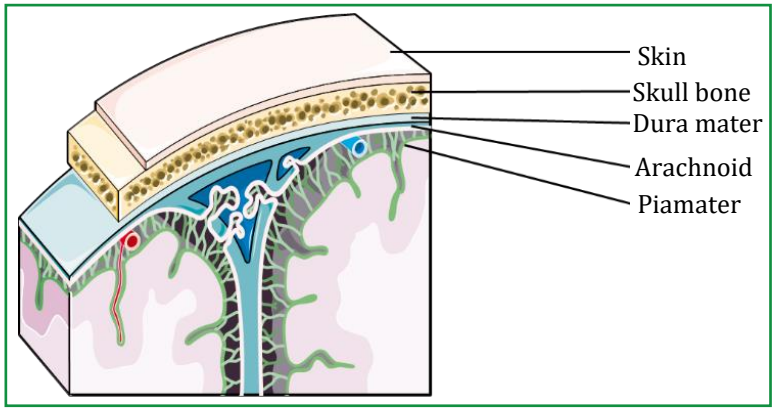
8. Central Neural System :



- It includes the brain and the spinal-cord.
- Brain's approximately 70-80% part develops in 2 year of age & complete development is achieved in 6 years of age & spinal cord develops completely in 4 to 5 years of age.
- The brain is the central information processing organ of our body, and acts as the 'command and control system'.

(A) Brain Meninges :

- Brain is covered by three membranes of connective tissue termed as meninges or menix.
- The human brain is well protected by the skull. Inside the skull, the brain is covered by cranial meninges consisting of an outer layer called dura mater, a very thin middle layer called arachnoid and an inner layer (which is in contact with the brain tissue) called pia mater.



- **Dura mater** is the first and the outermost membrane which is thick, strong and is made up of WFCT.
- **Arachnoid** middle and delicate layer and found only in mammals. (Mammalian character).
- **Piamater** Inner most layer which is thin, transparent and vascularised layer and is firmly attached to the brain.

(B) Cerebrospinal Fluid (CSF) :

- This fluid is clear and alkaline in nature just like lymph.
- CSF is present in ventricles of brain, subarachnoid space of brain & spinal cord.

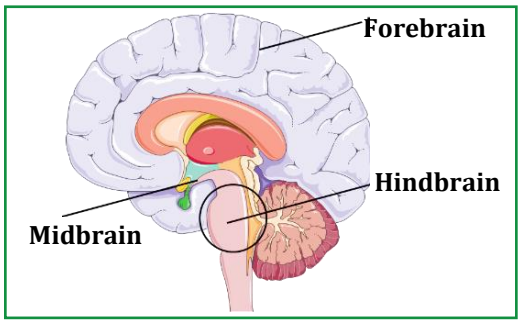
Functions of C.S.F. :

1. Protection of Brain : It acts as shock absorbing medium and works as cushion.
2. It provides buoyancy to the brain, so net weight of the brain is reduced from about 1.4 kg to about 0.18 kg.

(C) Brain :

The brain can be divided into three major parts-

(i) Forebrain
(ii) Midbrain
(iii) Hindbrain



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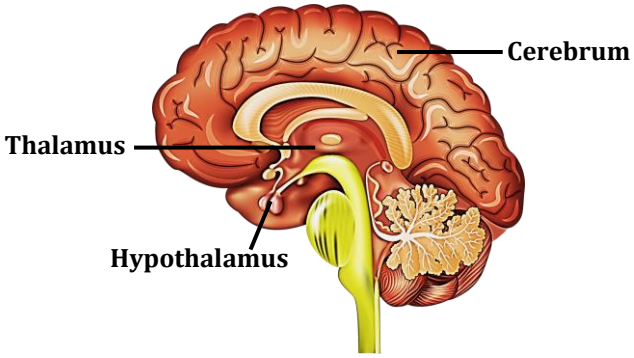
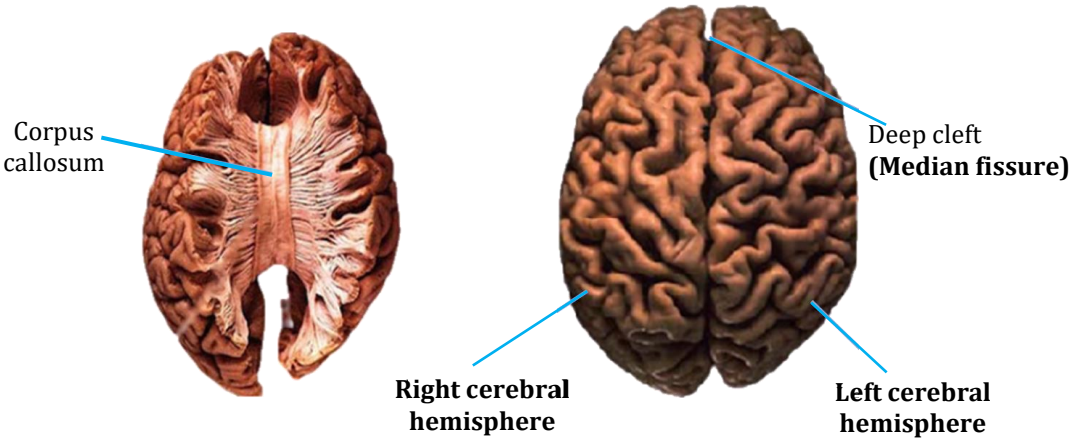
(i) Forebrain :

- The forebrain consists of cerebrum, thalamus and hypothalamus.

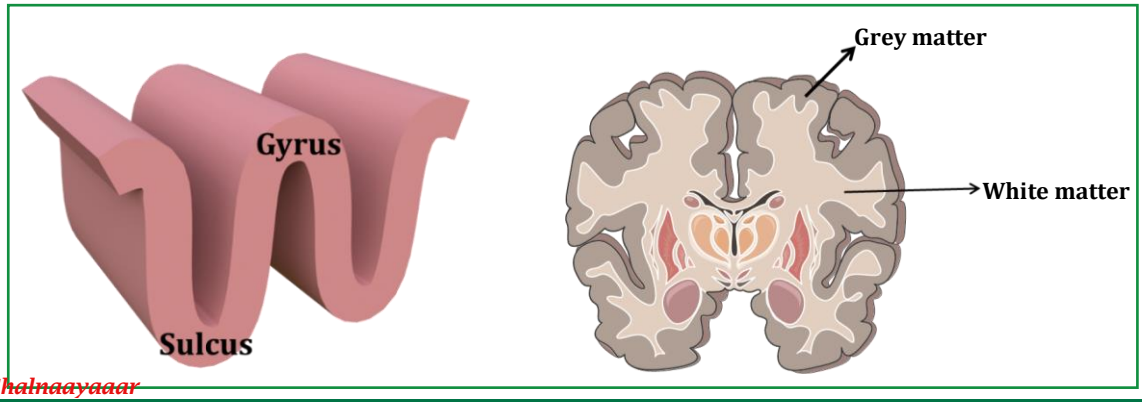


Cerebrum :

- Cerebrum forms the major part of the human brain. A deep cleft divides the cerebrum longitudinally into two halves, which are termed as the left and right cerebral hemispheres.



- The hemispheres are connected by a tract of nerve fibres called **'corpus callosum'**. (Largest commissure of brain) (Mammalian character).
- The outer part of cerebral hemisphere is called Cerebral cortex and thrown into prominent folds. Ridges are known as gyri while grooves are called sulci. Gyri and sulci increase the surface area of cerebrum. The cerebral cortex referred to as the gray matter due to its greyish appearance. The neuron cell bodies are concentrated here giving the colour.
- Fibres of the tracts are covered with the myelin sheath, which constitute the inner part of cerebral hemisphere. They give an opaque white appearance to the layer and, hence, are called the white matter.



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The cerebral cortex contains **three** types of functional areas :-

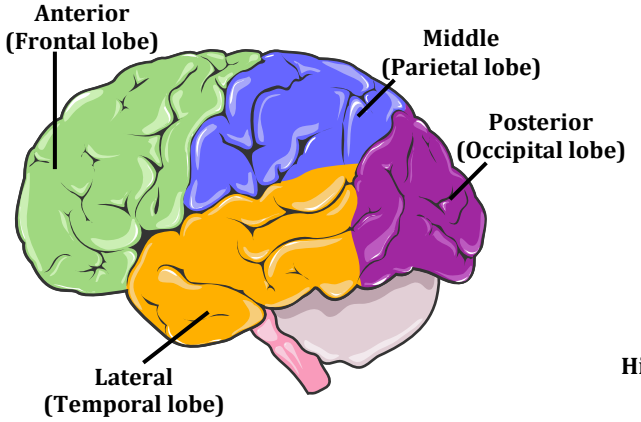
(a) **Sensory area-** Analysis of sensory impulses

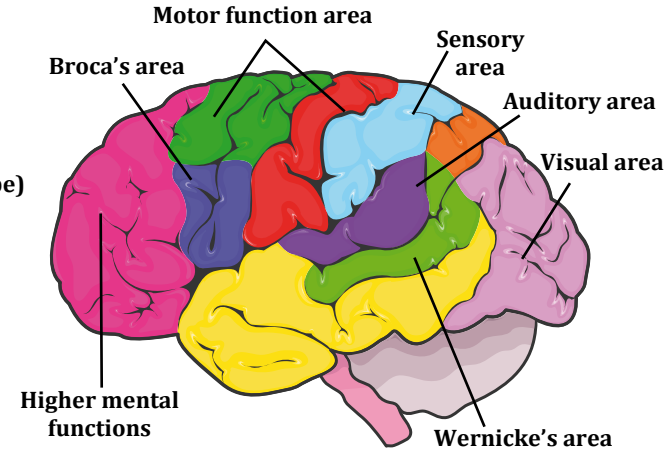
(b) **Motor area-** Generation of motor impulses

(c) **Association area-** These are large regions that are neither clearly sensory nor motor in function. They are responsible for certain complex functions like :-

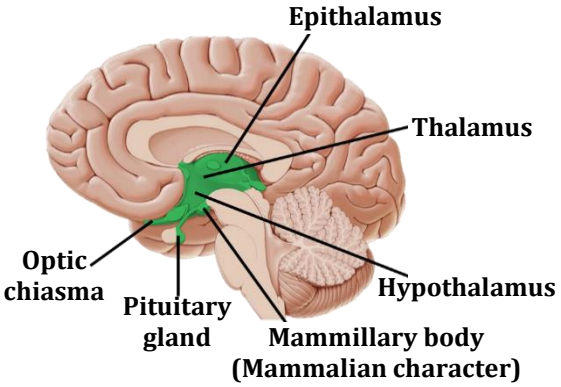
- **Intersensory associations :-** As you are aware that all sensory inputs like touch, sound, light, smell are sent to brain. These different sensation require association and inter connection with each other for their proper interpretation.
- **Memory :-** Memory of past events is recorded by the association areas and also with the different lobes of the cerebrum.
- **Communication :-** The ability of communication also controlled by the association areas of cerebral cortex.

Each cerebral hemisphere is divided into 4 lobes-Anterior, Middle, Posterior and Lateral.





- The cerebrum wraps around a structure called thalamus, which is a major coordinating centre for sensory and motor signaling. Epithalamus is upper or dorsal posterior part of thalamus. Pineal gland is connected with epithalamus. Thalamus acts as a relay center. (major coordinating center for sensory & motor signaling)



Hypothalamus :

- Another very important part of the brain called hypothalamus lies at the base of the thalamus. The hypothalamus contains a number of centres which control body temperature, urge for eating and drinking. It also contains several groups of neurosecretory cells, which secrete hormones called hypothalamic hormones.

Functions of Hypothalamus :

- Biological clock system
- Thermoregulation
- Behavior & Emotion
- Endocrine control
- ANS regulation
- Urge for eating and drinking

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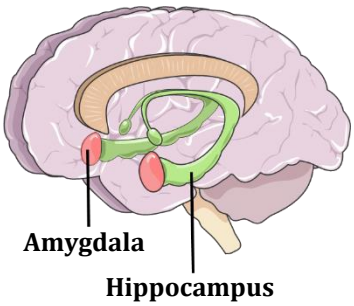
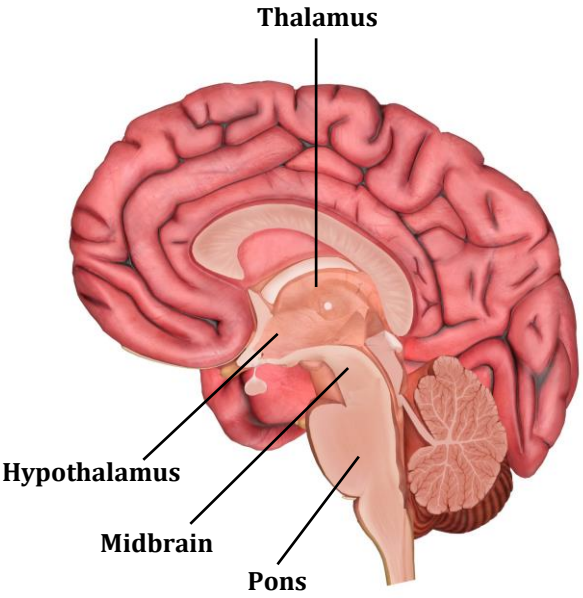
The inner parts of cerebral hemispheres and a group of associated deep structures like amygdala, hippocampus, etc., form a complex structure called the limbic lobe or **'limbic system'**. Along with the hypothalamus, it is involved in the regulation of sexual behavior, expression of emotional reactions (e.g. excitement, pleasure, rage, fear and motivation).



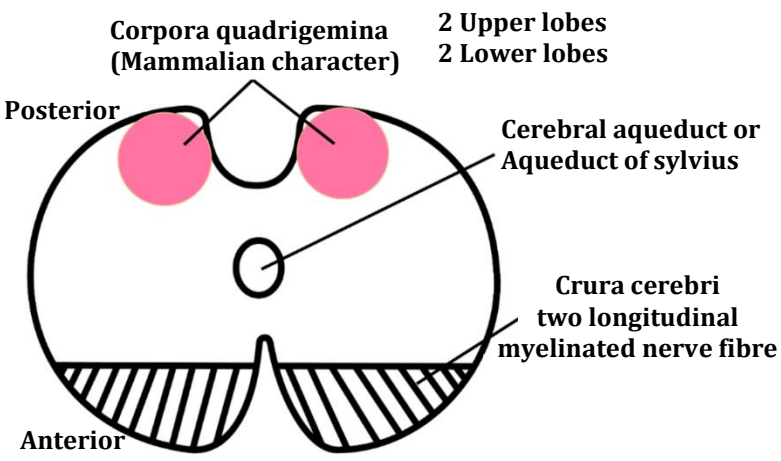
(ii) Mid Brain :

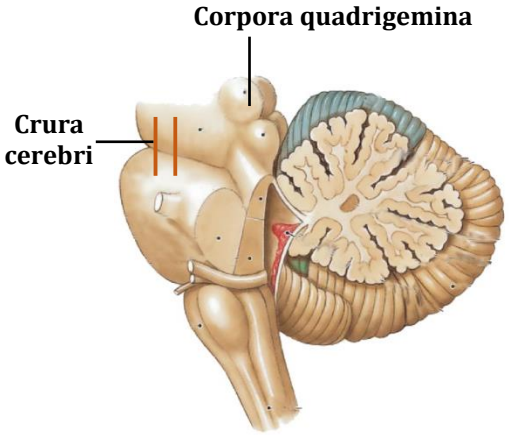
- It is a small part of brain. The midbrain is located between diencephalon of the fore brain and pons of the hind brain.
- A canal called Cerebral **aqueduct/ Aqueduct of sylvius** passes through the midbrain.
- Anterior part of midbrain contains two longitudinal myelinated nerve fibre called **cerebral peduncles** or **crus cerebri** or **crura cerebri**.
- On posterior part of mid brain four spherical projections are found called **colliculus** or **optic lobe**. Four colliculus are collectively called as **corpora quadrigemina**. (2 upper & 2 lower) **(Mammalian character)**.
- Mid brain and hind brain **(except cerebellum)** form the **brain stem**.



Function :

- The mid brain receives and integrates **visual, tactile and auditory inputs**.
- **Crura cerebri** controls the **muscle of limb** while **superior and inferior colliculus** are related with **pupillary (light) reflex** and **acoustic (Sound) reflex action** respectively.





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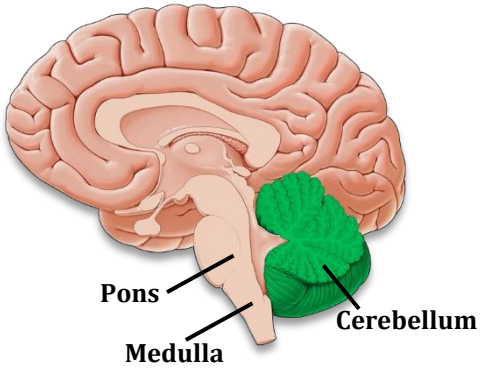
(iii) Hind Brain :

- The hind brain comprises pons, cerebellum and medulla (also called the medulla oblongata).

(a) Pons :

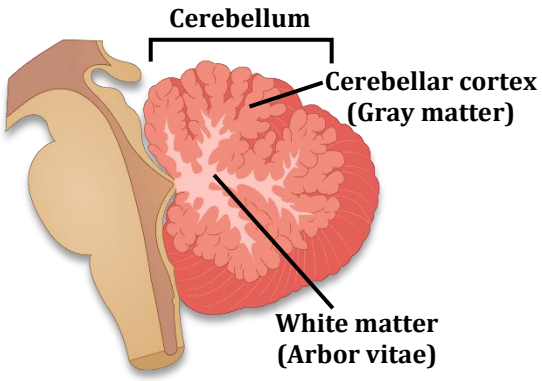
- It is a small spherical projection which is situated below the midbrain and upper side of medulla oblongata. It consists of many **transverse** and **longitudinal nerve fibres**. **Transverse nerve fibres** connects with cerebellum while **longitudinal nerve** fibre connect cerebrum to medulla oblongata.

  Function :- It regulates the breathing reaction through **pneumotaxic centre.**

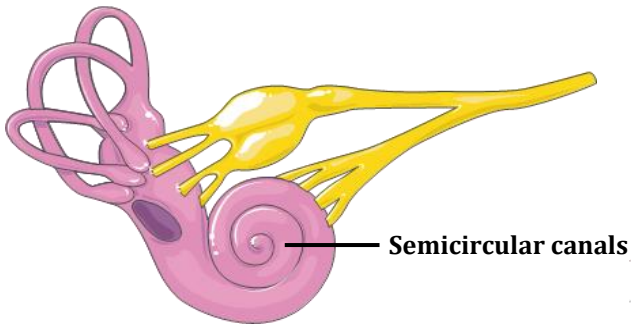


(b) Cerebellum :

- It is made up of 3 lobe (2 lateral lobe and 1 vermis). Both lateral lobes become enlarged and spherical in shape, so lateral lobe of cerebellum are also called as **cerebellar hemisphere**. Cerebellum has very convoluted surface in order to provide the additional space for many more neurons.
- Outer part of cerebellum is made up of gray matter while inner part is made up of white matter. White matter projects outside & forms a branched tree like structure known as **Arbor Vitae** (Tree of Life).



- **Functions:** The cerebellum integrates information received from the semi-circular canals of the ear and the auditory system and also by this portion of hind brain impulses are received from different voluntary muscles and joint.
- Due to this region, coordination of voluntary muscle through involuntary regulation is more developed in human as compared to other animals i.e. Body balance.
- The person who take alcohol in excess, their cerebellum gets affected as a result that person cannot maintain his balance and walking is disturbed.
- Thus, it is related with fine and skillfull voluntary movements.



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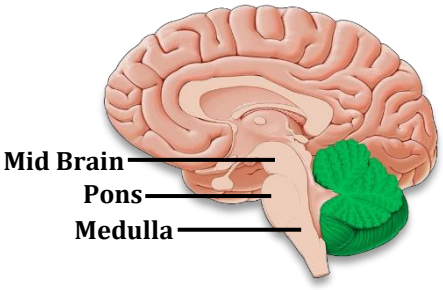
(c) Medulla Oblongata :



- Posterior part of hind brain is tubular and cylindrical in shape. Medulla of brain is connected to spinal cord.
- **Mid brain, pons** and **medulla** are situated in one axis and it is called as **Brain stem**.
- **Functions :** It is the most important part of brain which controls all the involuntary activities of the body ***e.g.*** cardiovascular reflex, respiration, metabolism, gastric secretion etc. As well as this act as conduction pathway for all impulses between spinal cord and remaining portions of brain.
- It is also concerned with cranial reflex action like sneezing reflex, salivation reflex, coughing reflex, swallowing reflex, vomiting reflex and yawning reflex.

BEGINNER'S BOX-3 — HUMAN BRAIN

1. Which lobe of cerebral hemisphere perform voluntary motor function of body ?
(1) Parietal lobe (2) Frontal lobe
(3) Occipital lobe (4) Temporal lobe

2. Which part of brain contains such area which are neither clearly sensory nor motor in function ?
(1) Cerebeller cortex (2) Cerebral cortex
(3) Grey matter of cerebrum (4) Both (2) and (3)

3. Voluntary activities of body are controlled by :-
(1) Diencephalon (2) Cerebrum (3) Crura cerebri (4) Cerebellum

4. Which part of nervous system is the central information processing part of act as command & control system?
(1) S.N.S. (2) P.N.S. (3) A.N.S. (4) C.N.S.

5. Grey matter includes :-
(1) Concentrated cell body (2) Unmyelinated axon
(3) Myelinated axon (4) (1) & (2) both

6. The layer of cells which covers the cerebral hemisphere is called :-
(1) Piamater (2) Duramater
(3) Cerebral cortex (4) Both (1) & (2)

7. Excitment, Pleasure, Rage fear & Motivation are combined function of :-
(1) Amygdala (2) Hippocampus
(3) Limbic lobe (4) All of these

8. Which of the following contains a number of centres which control body temperature urge for eating and drinking?
(1) Thalamus (2) Medulla oblongata
(3) Hypothalamus (4) Cerebrum

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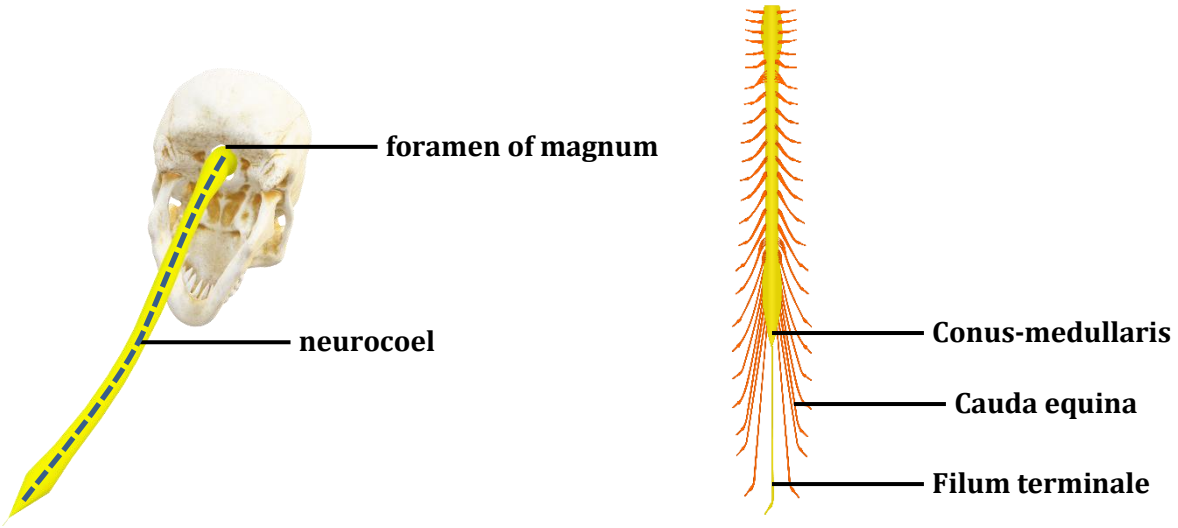
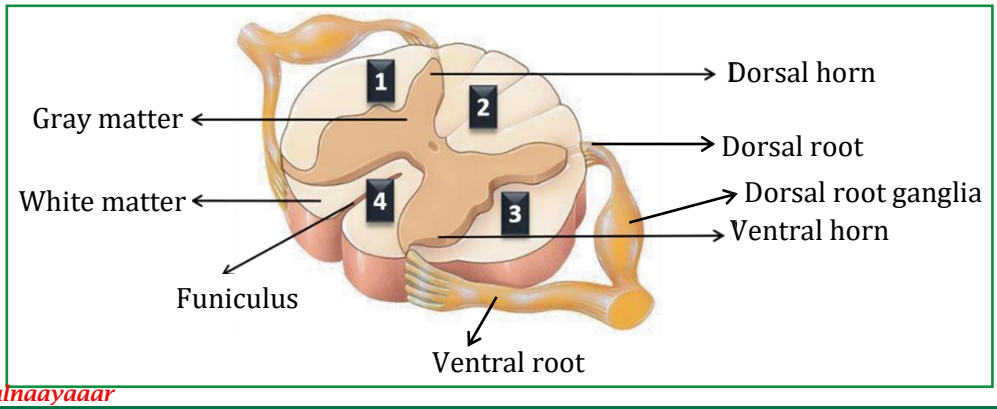
(D) Spinal Cord :

- Medulla oblongata comes out from **foramen of magnum** & continues in neural canal of vertebral column.



- Spinal cord is also covered by **Duramater, Arachnoid** & **piamater**. A narrow space is found between vertebra & duramater known as **Epidural space**.

- Length of spinal cord is 45 cm.
- Length of filum terminale is 20 cm.
- Weight of spinal cord is approximately 35 gm
- The outer-part of spinal cord is of white matter while inner-part contain gray matter.
- On the dorso-lateral & ventro-lateral surface of spinal cord, the gray matter (butterfly shaped) projects outside & forms one pair dorsal & ventral horn.
- Due to formation of dorsal & ventral horn white matter is divided in 4 segments & segment is known as Funiculus or white column.



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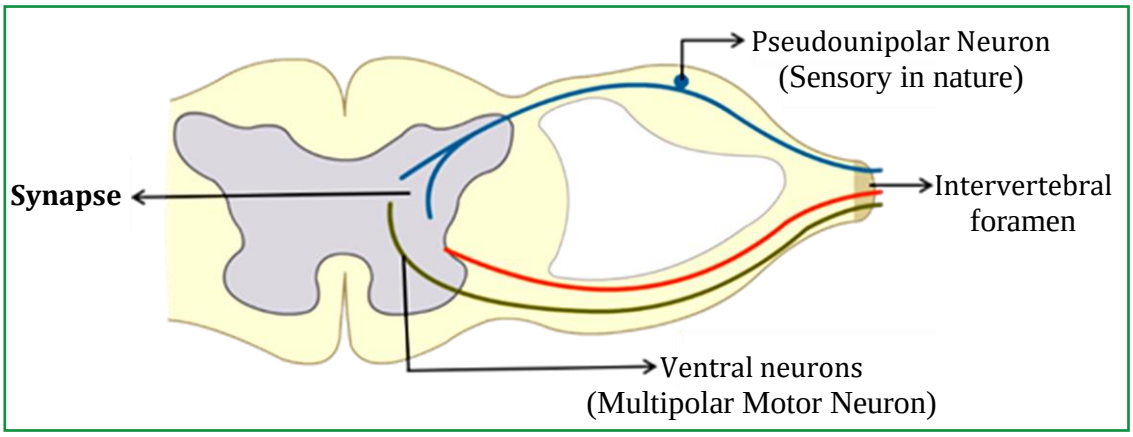
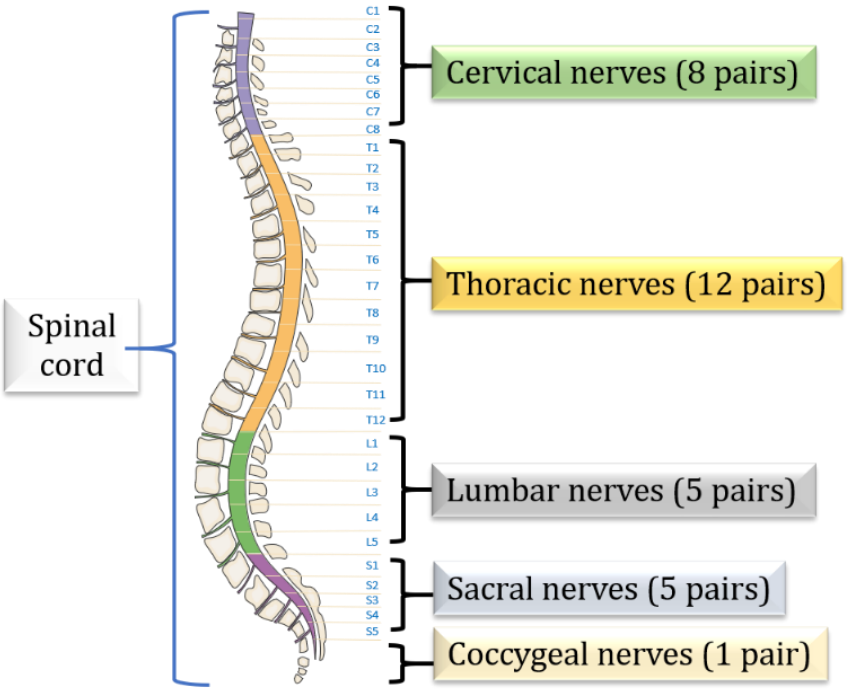
- Dorsal & ventral horn continue in a tube like (bundle of nerve fibres) structure known as **Dorsal root** and **Ventral root**.
- In root of dorsal horn, ganglia is present called **Dorsal root ganglia**.



- Sensory neurons are found in the dorsal root ganglia which is **pseudounipolar** in nature. Its axon extend & gets embedded into gray matter of spinal cord & make synapse with ventral root neuron.
- **Multipolar** motor neurons are found in the **ventral root**. Its cyton and dendron are embedded into gray matter of spinal cord where they make synapse with axon of sensory neuron.
- Both sensory & motor nerve fibers combinedly come out from intervertebral foramen & form spinal nerve.
- Spinal nerve & its branches are mixed type



Functions of spinal Cord

(1) It acts as a bridge between brain & organs of the body.

(2) It also provides relay path for the impulses coming from brain

(3) Spinal cord regulates and conducts most of the reflex action

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9. Peripheral Nervous System :

(A) Somatic Nervous System :

- All the nerves arising from **brain** and **spinal cord** are included in peripheral nervous system.
- Nerves arising from **brain** are called **cranial nerves**, and nerves coming out of **spinal cord** are called **spinal nerves**.
- **12-pairs** of **cranial nerves** are found in **reptiles**, **birds** and **mammals** but **amphibians** and **fishes** have **only 10-pairs** of cranial nerves.

S.No.	Name	Nature	Function
I	Olfactory	Sensory	Smell
II	Optic	Sensory	Sight
III	Occulomotor	Motor	Movement of eyeball
IV	Trochlear	Motor	Movement of eyeball.
V	Trigeminal (Dentist nerve)	Mixed	Teeth and Jaw muscles (mastication)
VI	Abducens	Motor	Movement of eyeball
VII	Facial	Mixed	Taste (anterior 2/3 part of Tongue) Facial expression
VIII	Auditory	Sensory	Hearing and equilibrium.
IX	Glossopharyngeal	Mixed	Taste (Posterior 1/3 part of tongue) & saliva secretion
X	Vagus (Pneumogastric)	Mixed	Visceral sensations and movements.
XI	Accessory spinal	Motor	Movement of pharynx, larynx.
XII	Hypoglossal	Motor	Movement of tongue.

(B) Autonomic or Visceral Nervous System :

- The autonomic nervous system or Visceral nervous system is a part of peripheral nervous system that comprises the whole complex of nerves fibres, ganglia and plexuses by which impulses travel from the central nervous system to the viscera and from the viscera to central nervous system.
- It controls activities inside the body that are normally involuntary, such as heart beat, peristalsis, sweating etc.

Autonomic neural system (ANS)

Sympathetic neural system

Sympathetic system is related with such visceral reactions. which increase the protection of body in adverse atmospheric conditions along with calorie consumption. (Causes loss of energy).

Parasympathetic neural system

Parasympathetic system is related with those reactions in which energy is conserved.

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Golden Key Points

- Longest cranial nerve is **Vagus nerve.**
- Largest cranial nerve is **Trigeminal nerve.**
- Smallest cranial nerve is **Abducens nerve.**
- Thinnest Cranial nerve **Trochlear nerve.**
- I, II and VIII cranial nerves are pure sensory nerves.
- III, IV, VI, XI and XII are pure motor cranial nerves.
- V, VII, IX, X are mixed cranial nerves.

BEGINNER'S BOX-4 SPINAL CORD & PNS

1. Which spinal nerve is not part of cauda equina ?
(1) Sacral spinal nerves. (2) Lumbar spinal nerves.
(3) Thoracic spinal nerves. (4) Coccygeal spinal nerve

2. Which structure is pure sensory ?
(1) Ramus dorsalis (2) Dorsal root (3) Spinal nerve (4) Ventral root

3. The lower most part of the spinal cord upto which, the nervous part extend :-
(1) Epidural space (2) Conus medullaris
(3) Cauda equina (4) Central canal

4. Sensory neurous found in the dorsal root Ganglia are :-
(1) Motor (2) Apolar (3) Pseudounipolar (4) Multipolar

5. The group of cranial nerves which are associated with the movement of eye ball are :-
(1) I, II, VIII (2) III, IV, VI (3) VII, IX, XII (4) III, IV, VII

6. Somatic nervous system is formed by :-
(1) Ramus dorsalis (2) Ramus communicans
(3) Ramus ventralis (4) Both (1) & (3)

7. Which of the following is **not** a function of parasympathetic nervous system ?
(1) Inhibition of peristalsis of alimentary canal
(2) Relaxation of arrector pilli muscles
(3) Erection of penis
(4) Contraction of urinary bladder

8. Which of the following nerves is purely sensory ?
(1) Occulomotor (2) Trochlear (3) Facial (4) Optic

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10. Reflex Action and Reflex ARC :

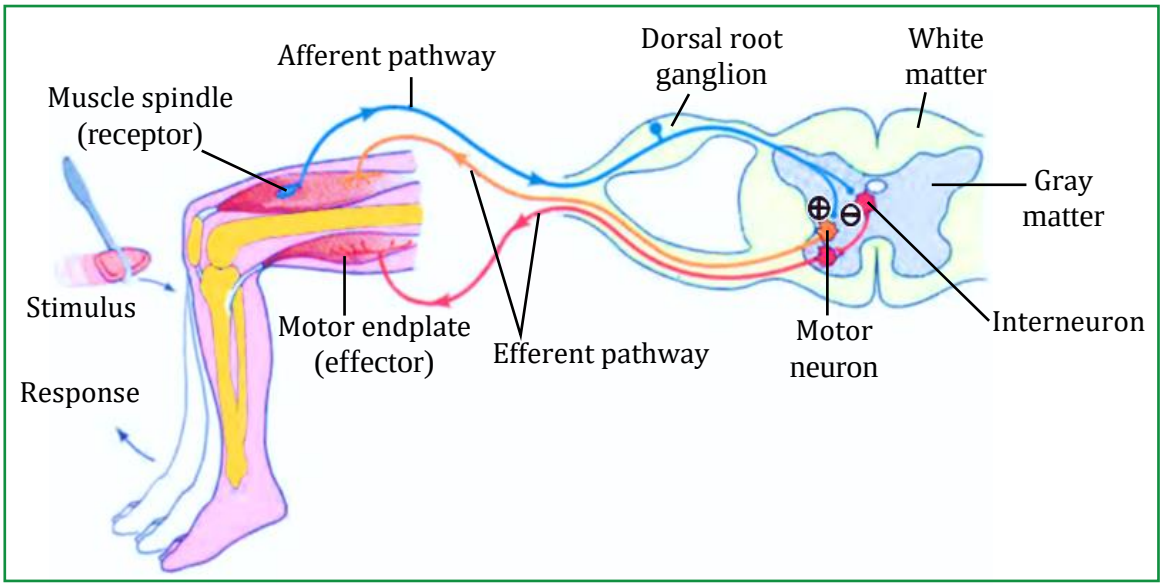
- The entire process of response to a peripheral nervous stimulation, that occurs involuntarily, i.e., without conscious effort or thought and requires the involvement of a part of the central nervous system is called a **reflex action**.
  e.g. sudden withdrawal of a body part which comes in contact with objects that are extremely hot, cold, pointed or animals that are scary or poisonous.
- The **reflex pathway** comprises at least **one afferent neuron** (receptor) and **one efferent** (effector or excitor) neuron appropriately arranged in a series.
- The afferent neuron receives signal from a sensory organ and transmits the impulse via dorsal nerve root into the CNS (at the level of spinal cord).
- The efferent neuron then carries signals from CNS to the effector.
- The stimulus and response thus forms a reflex arc as shown below in the knee jerk reflex.

On The Basis of Synapse :

(i) Monosynaptic

In this type of reflex arc, there is a direct synapse (relation) found between sensory and motor neurons, thus nerve impulse travels through only one synapse.

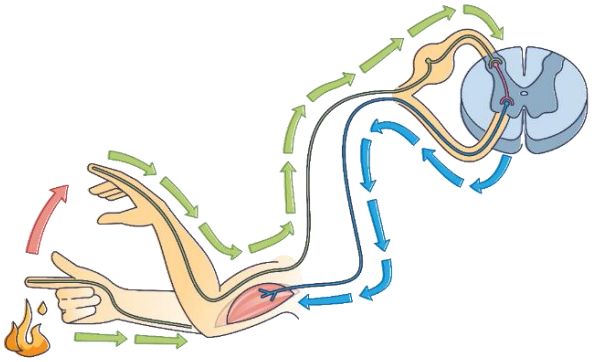
e.g. Stretch reflex/ Knee-Jerk reflex, Biceps tendon reflex and Triceps tendon reflex.



(ii) Polysynaptic

In this type of reflex arc, there are one or more small neurons found in between the sensory and motor neurons. These small neurons are called **connector neuron** or **inter neurons** or **internuncial neurons**.

e.g. withdrawal reflex.



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On The Basis of Previous Experiences :

Reflex actions are classified as :

(i) Conditioned reflex

Previous experience is required to complete these actions.

Initially these actions are voluntary at the time of learning and after perfection, these become involuntary.

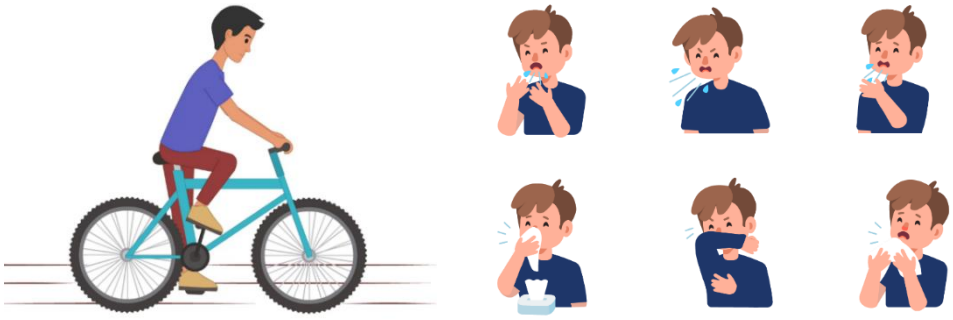
e.g. swimming, cycling, dancing, singing etc.

(ii) Unconditioned reflex

These actions do not require previous experience

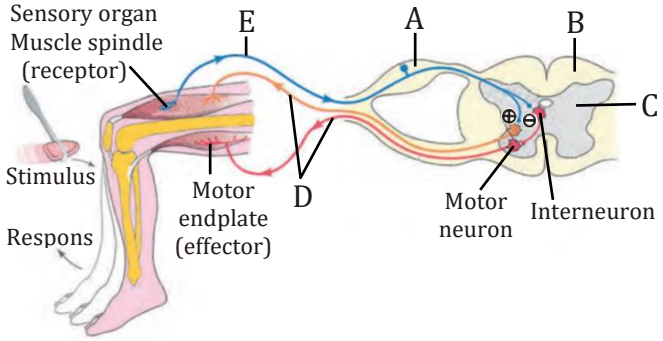
e.g. sneezing, coughing, yawning, sexual behavior for opposite sex partner, migration in birds etc.

(A) Conditioned reflex **(B) Unconditioned reflex**



BEGINNER'S BOX-5 REFLEX ACTION

1. The following diagrammatic representation of reflex action shows knee jerk reflex.



In which of the following options corrects words for all the 5 blanks (A to E) are indicated?

(1) A–Dorsal root ganglion, B–White matter, C–Gray matter, D–Afferent pathway, E–Efferent pathway

(2) A–Dorsal root ganglion, B–White matter, C–Gray matter, D–Efferent pathway, E–Afferent pathway

(3) A–Dorsal root ganglion, B–Gray matter, C–White matter, D–Efferent pathway, E–Afferent pathway

(4) A–Ventral root ganglion, B–White matter, C–Gray matter, D–Efferent pathway, E–Afferent pathway

2. The (A) neuron receives signals from sensory organ and transmit the impulse via (B) nerve root into the CNS.

(1) A – Afferent, B – Dorsal (2) A – Afferent, B – Ventral

(3) A – Efferent, B – Dorsal (4) A – Efferent, B – Ventral

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3. All of the following are examples of conditioned reflex except :-
(1) Swimming (2) Dancing (3) Playing piano (4) Sneezing

4. The ___(A)___ neuron carries the signal from CNS to the effector via ___(B)___ root.
(1) A–Efferent, B–Dorsal (2) A–Afferent, B–Dorsal
(3) A–Efferent, B–Ventral (4) A–Afferent, B–Dorsal

5. The direction of stimulus response is opposite in which of the following reflex action ?
(1) Biceps tendon reflex (2) Knee jerk reflex
(3) Tricep tendon reflex (4) Withdrawal reflex

6. At least how many afferent and efferent neuron and involved in any reflex action ?
(1) One afferent, one efferent neuron
(2) One afferent, two efferent, one interneuron
(3) One afferent, one efferent, two interneuron
(4) Two efferent, one efferent, one interneuron

BEGINNER'S BOX — ANSWERS KEY

BEGINNER'S BOX-1	Que.	1	2	3	4	5	6	7	8	9	
	Ans.	3	4	4	2	3	1	4	1	1	

BEGINNER'S BOX-2	Que.	1	2	3	4	5	6	7	8	9	
	Ans.	1	4	4	2	3	3	2	2	4	

BEGINNER'S BOX-3	Que.	1	2	3	4	5	6	7	8	
	Ans.	2	4	2	4	4	3	3	3	

BEGINNER'S BOX-4	Que.	1	2	3	4	5	6	7	8	
	Ans.	3	2	2	3	2	4	1	4	

BEGINNER'S BOX-5	Que.	1	2	3	4	5	6	
	Ans.	2	1	4	3	4	1	

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EXTRA POINTS

1. In human brain more than 100 billion neurons are present.
2. Each neuron cell connect with 25,000 other cell.
3. **Glycine** is neuro inhibitory hormone present in spinal cord.
4. **Glutamic acid** is mainly used by our brain cells as excitatory neurotransmitter.
5. The velocity of nerve- impulse is 5 to 50 times more faster in Myelinated nerve - fibres than in Non-myelinated nerve -fibres.
6. Cerebrum is the centre of following:-

   (1) Intelligence **(2)** Emotion

   (3) Will- power **(4)** Memory

   (5) Consciousness **(6)** Experience

   (7) Knowledge **(8)** Voluntary control

   (9) Laughing and weeping **(10)** Defaecation and micturition.
7. Increase in the amount of cerebro- spinal fluid is a diseased condition termed as the **hydrocephalus**
8. Acetylcholine is synthesized by the Mitochondria.
9. **Reticular activating System :** It is special sensory fibre which is situated in Brain stem & further go into Thalamus. It is related with **consiousness**, **alertness** & **awakening**. Therefore it is also called **gate keeper of consiousness**.
10. **Parkinson's disease :** It occurs due to hyposecretion of dopamine which creates rigidity is muscle leads to muscle tremors. It begin from progressive degeneration of neuron of basal nuclei ultimately creates mask like face.
11. **Alzheimer's disease :** In this disease, the cerebral cortex is atrophied and ultimately the ventricle enlarges. Symptoms consist loss of memory particularly recent memory due to hyposecretion of acetylcholine.
12. **Cavities of brain (Ventricles)**
    - Paracoel or Lateral ventricle or I & II ventricle (largest) – Found in Cerebral hemisphere
    - III Ventricle or Diocoel – Found in Diencephalon

    Note: *I & II open in III Ventricle via Foramen of Monro*
    - IV Ventricle – Cavity of hind brain.

    Note: *Cavity of Medulla Oblongata – Metacoel*

    Cavity of Spinal cord – Neurocoel/Central Canal

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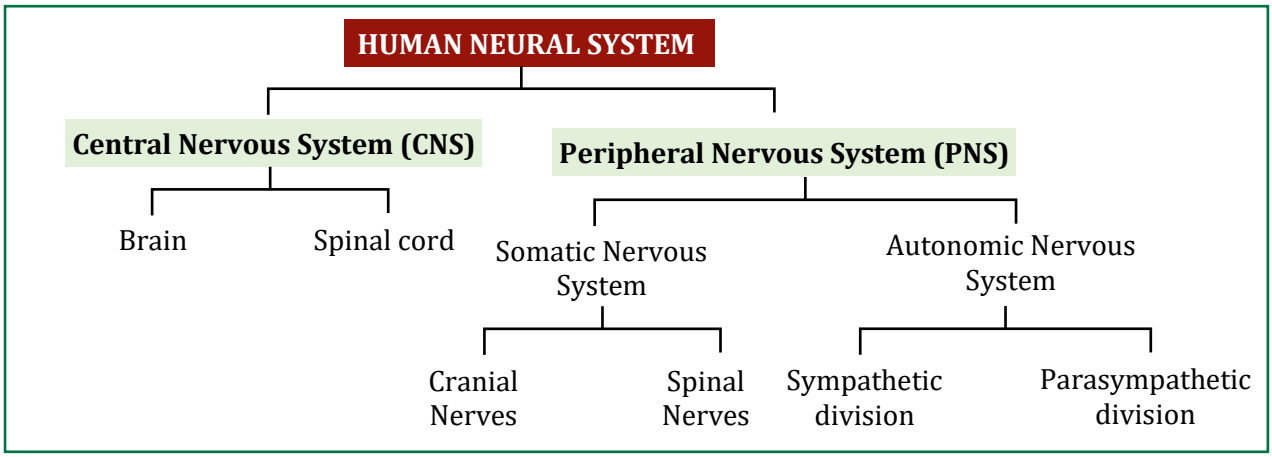
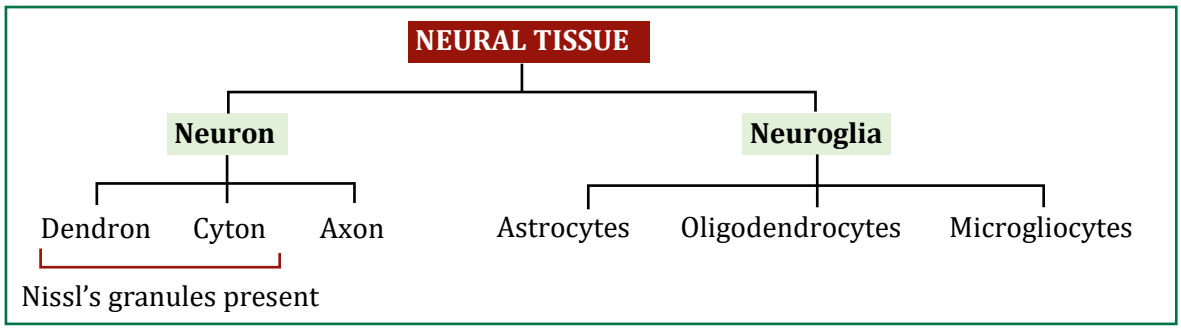
ESSENCE





GENERATION OF NERVE IMPULSE

Process	Na^+-K^+ pump	Passive diffusion	Na^+ VGC	K^+ VGC	Potential with value	Inside Charge after the event
Polarisation	✓	✓	×	×	RMP (–60 to –85mV)	Negative
Depolarisation	×	✓	✓	×	+30 to +45 mV	Positive
Repolarisation	✓	✓	×	✓	–70 mV	Negative
Hyperpolarisation	✓	✓	×	✓	–85 mV	Negative

TYPE OF SYNAPSE

	Electrical	Chemical
(i) Conduction	Fast	Slow
(ii) Synaptic cleft	0.2 nm	> 20 nm
(iii) Neurotransmitter in synaptic cleft	Absent	Present
(iv) Occurence in body	Rare in our body	Most common
(v) Synaptic delay	Absent	Present
(vi) Blocking	Cannot be controlled	Controlled by neurotransmitter

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SPECIAL NOTE : MAJOR FUNCTIONS OF THE BRAIN

PART OF BRAIN	FUNCTION
Frontal lobe of cerebrum (Fore-brain)	Voluntary movements
Cerebellum (Hind brain)	Balance of the Body
Hypothalamus and Medulla oblongata	Functioning of the vital involuntary organs
Hypothalamus	Thermoregulation
Hypothalamus	Hunger and thirst
Pineal gland and Hypothalamus	Circadian (24 hour) rhythms of our body
Hypothalamus	Activities of endocrine glands
Cerebrum	Higher functions
Cerebrum **(Hippocampus)**	Memory
Cerebrum :- Parietal lobe Occipital lobe Temporal lobe	Processing and analysis of various sensation
Hypothalamus and limbic System **(amygdala)**	Emotion and Human behaviour

- Medulla oblongata comes out from **foramen magnum** & continues in neural canal of vertebral column, the continued part of MO is known as Spinal cord. It extends from base of skull to (L_1) lumbar vertebra.
- All the nerves arising from brain and spinal cord are included in peripheral nervous system. Nerves arising from brain are called **cranial nerves**, and nerves coming out of spinal cord are called **spinal nerves**.
- **12-pairs** of cranial nerves are found in reptiles, birds and mammals but amphibians and fishes have only **10-pairs** of cranial nerves.
- In Human only **31 pairs** of spinal nerves are found.
- Overall control of the autonomic nervous system is maintained by centres in the **medulla** (a part of the hind brain) and **hypothalamus**.
- *The entire process of response to a peripheral nervous stimulation, that occurs involuntarily i.e. without conscious effort or thought and requires the involvement of a part of the central nervous system is called a* ***reflex action****.*
- The reflex pathway comprises at least one afferent neuron (receptor) and one efferent (effector) neuron appropriately arranged in a series.

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